The Effectiveness of Web-based Curriculum Materials to Support Enactment of a Technology-Integrated Science Curriculum

Alec M. Bodzin, Lehigh University

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Program Abstract

The implementation of Web-based curriculum materials that includes substantial educative materials designed to support the professional growth of science teachers to implement Web GIS tectonics investigations with limited face-to-face professional development is presented.

Proceedings Abstract

As part of a systemic science education reform initiative, a series of six Web GIS tectonics investigations designed to augment the middle school Earth science curriculum was developed. The curriculum includes educative materials and embedded supports designed to aid teacher development of both tectonics content knowledge and pedagogical content knowledge for effective curriculum enactment. These supports were developed to address the need to provide "just in time" professional development experiences to help educate teachers about important tectonics concepts and to support their development of geospatial pedagogical content knowledge to teach with a novel Web-based curriculum. A curriculum implementation study was conducted with twelve grade 8 urban middle level science teachers that implemented the Web GIS investigations with 1,124 students during the 2012-13 school year. Data sources included a student pretest-posttest tectonics measure, 33 classroom observations, a post-implementation survey and a focus group interview. Students' tectonics content knowledge and geospatial thinking and reasoning applied to tectonics achieved statistically significant gains from pretest to posttest ($p < .001$) with large effect sizes. Results indicated that the curriculum materials were effective in supporting the science teachers' professional growth during the curriculum enactment and supported their teaching of the Web GIS investigations. Most teachers perceived that both their tectonics content knowledge and geospatial thinking and reasoning skills were enhanced as a direct result of their use of the curriculum. Teacher understandings of how Web GIS can be used effectively in science classroom instruction to achieve learning goals was also enhanced as a result of their direct interactions with the curriculum materials. This project illustrates a model for designing technology-integrated science curriculum with educative curriculum materials to support the professional growth of teachers when face-to-face professional development time is limited.

The available time within a school year to provide inservice science teachers with quality face-to-face professional development to adopt new science education technology-integrated curriculum is limited. During the past years, we have partnered with a unionized urban school district in a systemic middle level science curriculum reform effort. During this time, school financial resources have been extremely limited and science teachers have been allowed to attend only two or three days of face-to-face professional development during the school year. To address this professional development time constraint, we have developed and implemented a different mechanism of providing science teacher professional development that includes substantial materials designed to promote professional growth within Web-based curriculum materials.

Curriculum materials can be designed to incorporate professional development learning opportunities for science teachers to assist them with deepening their understandings of science content in addition to accomplishing instructional goals for their students. They may influence teacher decision-making by conveying instructional practices, providing appropriate science content materials, or providing pedagogical implementation ideas (Davis & Krajcik, 2005; Davis & Varma, 2008). Curriculum designers can develop learning materials that better accommodate instruction by moving away from the traditional mode of instructional design models of curriculum as a “one-size-fits all students” model and instead provide for flexible adaptations to instructional implementation. Such curriculum designs can provide for different modes of instruction that are important given the diverse nature of students and their abilities in science classrooms.

When curriculum materials are expected to take on the role of change agent and transform teacher practice – as in a systemic reform initiative – the challenges of effective implementation are heightened. Unfortunately, research has shown that there are many obstacles that teachers face when they attempt to use curriculum materials that are based on an instructional approach to teaching and learning that differs from their own experiences as teachers or learners (Stein, Grover, & Henningsen, 1996). This is especially true when teachers enact instructional materials that utilize geospatial technologies (GT) to support inquiry-based learning environments. Studies have shown that teachers may experience technical issues pertaining to the interface design of software, have time constraints to learn how to use GT software applications to effectively teach students, undergo difficulty with adapting developed learning materials to easily integrate into their own school curriculum, and may lack pedagogical content knowledge conducive to teaching with GT in classroom settings (Baker & Bednarz, 2003; Patterson, Reeve, & Page, 2003; Trautmann & MaKinster, 2010).

One way of addressing these challenges is to design curriculum materials to promote the pedagogical design capacity of teachers - that is their ability to perceive and mobilize curriculum materials and resources for effective instructional enactment (Brown, 2009). The concept of pedagogical design capacity suggests that curriculum materials can be designed in ways to facilitate productive use by teachers to accomplish learning goals. This implies the importance of including embedded supports within the curriculum in the form of educative curriculum materials - features of curriculum materials designed to support teacher pedagogical content knowledge in addition to student learning (Davis & Krajcik, 2005). Educative curriculum materials have the potential to support teacher learning in a variety of ways. For example, they may help teachers learn how to anticipate and interpret what learners may think about or do in response to instructional activities (Remillard, 2000). They may also support teachers' learning of subject matter (Schneider & Krajcik, 2002; Wang & Paine, 2003). Educative curriculum materials can also include pedagogical implementation supports provided in the materials in order to engage teachers in the ideas underlying curriculum developers' decisions (Davis and Krajcik, 2005; Remillard, 2000). In these ways, educative curriculum materials can promote a teacher's pedagogical design capacity, or his or her ability to use instructional resources and the supports embedded in curriculum materials to adapt curriculum to achieve productive instructional ends (Brown, 2009).

Instructional Context and Supports

In partnership with an urban school district, we developed a series of six Web GIS tectonics investigations designed to augment the middle school Earth science curriculum. The investigations are aligned to Disciplinary Core Ideas: Earth and Space Science from the National Research Council's (2012) *Framework for K-12 Science Education* ESS2.B: Plate Tectonics and Large Scale System Interactions. Each Web GIS investigation was designed with eight instructional events that are based on current learning theories (Black & McClintock, 1996; Collins & Stevens, 1983; Eisenkraft, 2003; Gagné, 1985; Jonassen, 1997; 1999):

1. Elicit prior understandings of lesson concepts.
2. Present authentic learning task.
3. Model learning task.
4. Provide worked example.
5. Perform learning task.
6. Scaffold learning task.
7. Elaborate task with additional questions.
8. Review activity concepts.

The Tectonics investigations are available at: http://www.ei.lehigh.edu/eli/tectonics

Below is a brief overview of the investigations:

Geohazards and Me: What geologic hazards exist near me? Which plate boundary is closest to me?

In this investigation, students develop a personnel connection to geologic hazards, They discover where the most recent earthquake occurred near their geographic location and where the nearest volcano is located. They also investigate how geologic hazards are distributed around the globe and infer how this is related to plate tectonics.

How do we recognize plate boundaries?

In this investigation, students use tectonics data to identify the eastern and western boundaries of the North American Plate. They analyze earthquake epicenter and volcano data to determine the boundaries of the North American Plate and analyze the movement of the surrounding plates to determine plate boundary types (divergent, convergent, or transform).

How does thermal energy move around the Earth?

In this investigation, students locate areas where heat escapes from the Earth's interior from the hot mantle. They investigate how surface heat flow (loss) is distributed around the Earth and its relationship to plate boundaries. They also explore geologic features on the Earth's surface which are associated with heat loss.

What happens when plates diverge?

In this investigation, students locate different divergent boundaries and study their history. They investigate how tectonic strains are accommodated at the plate boundary by examining earthquake and fault data and calculating the half-spreading rate of a plate boundary. They also investigate features of passive margins, areas along divergent boundaries where continental crust joins oceanic crust.

What happens when plates move sideways past each other?

In this investigation, students locate oceanic and continental transform boundaries and study their history. They investigate an oceanic transform fault within the Charlie-Gibbs Fracture zone, using seismic and age of the ocean floor data. They also investigate a continental transform boundary, the San Andreas Fault zone, and the seismic hazards associated with living in this area using earthquake data and historical photographs.

What happens when plates collide?

In this investigation, students analyze the distribution of earthquakes and volcanoes to learn about plate collision at an ocean-ocean subduction zone. They determine the inclination of subducted plates along convergent plate boundaries, and discover the relationship between the Aleutian Islands, volcanoes, and subduction zone types. In addition, they learn about the types of landforms created by continents colliding at convergent zones.

The investigations include a series of educative curriculum materials designed to support teacher implementation of the investigations. These support features include:

- *Instructional Framework* section. This section provides teachers with an overview of the curriculum framework, design principles, and the instructional model for teaching with geospatial technologies. This section also presents science education standards alignment.
- *Teacher Guides*. Instructional guides designed to support a teacher's implementation of a specific learning activity. They include detailed information for viewing and analyzing geospatial data during the learning activities and also include implementation suggestions and ideas to adapt a learning activity for different types of learners.
- *Support Materials* section. This section includes Web pages that contain text, graphics, and animations designed to enhance a teacher's content knowledge about a particular tectonics topic that are unique to our Web GIS learning activities. This section also includes tutorial videos that provide detailed overviews of each Web GIS learning activity.

- *Instructional sequence* Web pages. These Web pages include a recommended implementation sequence for each investigation, implementation suggestions, and hypertext links to content supports and specific materials needed for the learning activities including the Web GIS, assessments, student investigation sheets and handouts, teacher guides, and Web GIS tutorial videos.

The curriculum includes educative materials and embedded supports designed to assist teacher development of both tectonics content knowledge and pedagogical content knowledge for effective curriculum enactment. We developed these supports to address the need to provide "just in time" professional development experiences to help educate teachers about important tectonics concepts and to support their development of geospatial pedagogical content knowledge to teach with a novel curriculum that promotes geospatial thinking skills applied to tectonics concepts. The teachers in this study received two days of face-to-face professional development prior to implementing the Web GIS investigations with their students.

Goal of this Study

The goal of this study was to investigate the effectiveness of the curriculum and educative materials to support science teachers' professional growth during the curriculum enactment of the Web GIS investigations.

Methodology

Twelve grade 8 urban middle level science teachers implemented the Web GIS investigations with 1,124 students during the 2012-13 school year. Thirty-three observations were conducted in the teachers' classrooms during the curriculum enactment with a fidelity of implementation protocol that examined adherence to the eight instructional events described above. After the curriculum implementation, the teachers completed a post-implementation survey consisting of 24 Likert items and 4 open-ended response items designed to examine teachers' professional growth through the use of both the curriculum support materials and the implementation of the Web GIS investigations. A focus group was also conducted with the teachers using a 6-item questionnaire protocol that focused on the effectiveness of the materials to support teacher enactment of the Web GIS investigations. The students completed a 34-item pre-posttest tectonics content knowledge and geospatial skills measure (Cronbach's alpha = 0.86) before and after the curriculum implementation.

Findings

The teachers enacted all eight key elements of the instructional model for more than half (60.6%) of the observed investigations. The last key element, *review activity concepts*, was omitted for eight observed investigations due to time constraint issues; that is, the 46-minute class period ended before the concept was reviewed and was not revisited during the next class meeting. Pedagogical implementation was mostly consistent for each teacher for each ability track level they taught. There was little variability among the teachers with regards to adherence to the key elements of the instructional model during the curriculum enactment. For the majority of observed lessons, instruction was highly structured with much explicit modeling using a projected image. Whole-group scaffolding was used for geospatial analysis as students worked on individual laptops or in dyads to complete the investigations. Most teachers did not modify the instructional materials and enacted the investigations as designed. Observational protocol data found students' engagement and involvement in the learning activities was high.

The majority of teachers completed all six Web GIS investigations and most teachers (83.7%) stated they either always or frequently adhered to all 8 events in the spatial learning design model. Analysis of the teachers' survey responses indicated they believed the eight key elements of the instructional model improved their students' understandings of Earth science concepts and processes (Table 1). All but one teacher stated they believed that using Web GIS tectonics investigations enhanced what they typically did in their classrooms to teach Earth science.

We analyzed the teachers' perceived impact of the curriculum materials to support their pedagogical content knowledge related to teaching tectonics with Web GIS from both the survey responses and the focus group interview. Results indicated that the curriculum materials were effective in supporting the science teachers' professional growth during the curriculum enactment and supported their teaching of the Web GIS investigations. Most teachers perceived that both their tectonics content knowledge and geospatial thinking and reasoning skills were enhanced as a direct result of their use of the curriculum (see Tables 2 and 3). Teacher understandings of how Web GIS can be used effectively in science classroom instruction to achieve learning goals (pedagogical content knowledge) were also enhanced as a result of their direct interactions with the curriculum materials (Table 4). Many teacher survey responses noted that interactions with the curriculum enhanced their capacity to adapt their instruction using geospatial curriculum learning materials for effective instructional enactment.

Students' tectonics content knowledge and geospatial thinking and reasoning applied to tectonics achieved statistically significant gains from pretest to posttest ($p < .001$); see Table 5. The effect sizes were large (>1.00, using the cutoff .80 from Cohen, 1988). This result also supports that the embedded educative curriculum materials helped to support teachers' implementation.

Concluding Thoughts

Many science teachers have not had professional development experiences that foster sufficient science pedagogical content knowledge to adopt and implement Web GIS in science classrooms that promotes science learning and the development of geospatial thinking and reasoning skills. Providing science teachers with pedagogical content knowledge and Web GIS investigations that promote geospatial thinking and reasoning skills applied to tectonics concepts is an important priority within the science education community and therefore contributes significantly to science teacher education.

In this project, the teachers received only two days of face-to-face professional development prior to implementing the Web GIS investigations as part of their curriculum. This time provision reflects the reality of many urban school districts that have limited resources available to provide their teachers with face-to-face professional development experiences. This project illustrates a model for designing technology-integrated curriculum with educative curriculum materials that can be used to support the professional growth of teachers when face-to-face professional development time is limited. The designs of the supported features we have developed can serve as a model to other science teacher educators and curriculum developers to help promote the teaching and learning of science with Web GIS and other instructional technologies. We contend that providing embedded professional development within curriculum materials is a necessary and transformative educational mechanism, since many professional development constraints exist for teachers to adopt and implement reform-based science curriculum in urban school systems (Fishman, et al., 2003).

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Table 1

Degree to which instructional events improved students' understanding of Earth science. (n=12) Scale: 1 (Not at all) to 4 (A great deal)

To what degree do you believe that the following instructional events improved your students' understandings of Earth science concepts and processes?	**Not at all % (n)**	**Somewhat % (n)**	**Moderately % (n)**	**A great deal % (n)**	**Mean**
Elicit prior understandings of lesson concepts.	8.3% (1)	8.3% (1)	33.3% (4)	50.0% (6)	3.25
Present authentic task.	0.0% (0)	8.3% (1)	16.7% (2)	75.0% (9)	3.67
Model task.	0.0% (0)	0.0% (0)	33.3% (4)	75.0% (9)	3.69
Provide worked example.	0.0% (0)	0.0% (0)	25.0% (3)	75.0% (9)	3.75
Ask learners to perform task.	0.0% (0)	0.0% (0)	33.3% (4)	66.7% (8)	3.67
Scaffold task.	0.0% (0)	8.3% (1)	33.3% (4)	58.3% (7)	3.50
Ask learners additional questions to elaborate task.	0.0% (0)	16.7% (2)	50.0% (6)	33.3% (4)	3.17
Review activity concepts.	0.0% (0)	8.3% (1)	25.0% (3)	66.7% (8)	3.58

Table 2
Teacher knowledge gains while using support materials. (n=12)
Scale: 1 (Strongly Disagree) to 5 (Strongly Agree)

Item **Please indicate your agreement with the following statements.**	**Strongly Disagree % (n)**	**Disagree % (n)**	**No Opinion % (n)**	**Agree % (n)**	**Strongly Agree % (n)**	**Mean**
My knowledge about Web GIS increased as I used the support materials (Teachers Guide, videos) provided on the ELI Tectonics Web site.	0.0% (0)	0.0% (0)	8.3% (1)	75.0% (9)	16.7% (2)	4.08
My geospatial thinking and reasoning skills increased as I used the support materials (Teachers Guide, videos) provided on the ELI Tectonics Web site.	0.0% (0)	0.0% (0)	33.3% (4)	41.7% (5)	25.0% (3)	3.92
My content knowledge about tectonics increased as I used the support materials (Teachers Guide, videos, content background pages) provided on the ELI Tectonics Web site.	0.0% (0)	8.3% (1)	16.7% (2)	50.0% (6)	25.0% (3)	3.92
My understanding to how Web GIS can be used to promote science learning increased as I used the support materials (Teachers Guide, videos, content background pages) provided on the ELI Tectonics Web site.	0.0% (0)	0.0% (0)	16.7% (2)	50.0% (6)	33.3% (4)	4.17

Table 3
Teacher knowledge gains during implementation of Web GIS with students. (n=12)
Scale: 1 (Strongly Disagree) to 5 (Strongly Agree)

Item **Please indicate your agreement with the following statements.**	**Strongly Disagree % (n)**	**Disagree % (n)**	**No Opinion % (n)**	**Agree % (n)**	**Strongly Agree % (n)**	**Mean**
My knowledge about Web GIS increased as I used the ELI Tectonics Web GIS investigations.	0.0% (0)	8.3% (1)	8.3% (1)	33.3% (4)	50.0% (6)	4.25
My geospatial thinking and reasoning skills increased as I used the ELI Tectonics Web GIS investigations.	0.0% (0)	8.3% (1)	8.3% (1)	50.0% (6)	33.3% (4)	4.08
My content knowledge about tectonics increased as I used the ELI Tectonics Web GIS investigation with my students.	0.0% (0)	16.7% (2)	8.3% (1)	41.7% (5)	33.3% (4)	3.92
My understanding of how Web GIS can be used to promote science learning increased as I used the ELI Web GIS investigations.	8.3% (1)	0.0% (0)	16.7% (2)	41.7% (5)	33.3% (4)	3.92

Table 4
End of Tectonics unit implementation survey responses pertaining to the usefulness of curriculum support materials (n=12)
Scale: 1 (Strongly Disagree) to 5 (Strongly Agree)

Item **CURRICULUM MATERIALS** **Please indicate your agreement with the following statements:**	**Strongly Disagree % (n)**	**Disagree % (n)**	**No Opinion % (n)**	**Agree % (n)**	**Strongly Agree % (n)**	**Mean**
The teacher support materials (teacher guides, content materials, FAQs) helped me to use the Web GIS with my students.	0.0% (0)	0.0% (0)	8.3% (1)	41.7% (5)	50.0% (6)	4.42
The curriculum materials provided me with information to help my students view, manipulate, and analyze rich data sets using the Web GIS.	0.0% (0)	8.3% (1)	0.0% (0)	66.7% (8)	25.0% (3)	4.08
The teacher support materials (teacher guides, content materials, videos) provided pedagogical supports for me to think about how I might adapt my instructional practices to meet the needs of my students.	0.0% (0)	8.3% (1)	25.0% (3)	8.3% (1)	58.3% (7)	4.17
The instructional materials (student handouts, assessment items) could easily be modified to address the needs of my students.	0.0% (0)	8.3% (1)	16.7% (2)	16.7% (2)	58.3% (7)	4.25
The teacher support materials (teacher guides, content materials, videos) introduced me to ways of teaching Earth science with Web GIS.	0.0% (0)	0.0% (0)	16.7% (2)	33.3% (4)	50.0% (6)	4.33

Table 5
Tectonics Achievement for Pretest and Posttest and Paired-Sample T Tests (Listwise N = 1025)

	Pretest Mean (SD)	Posttest Mean (SD)	*t*	Effect Size
Entire Assessment	17.57 (5.67)	24.79 (6.03)	49.45***	1.23
Geospatial Subscale	9.61 (3.73)	13.71 (3.84)	39.50***	1.08
Non-Geospatial Subscale	7.96 (2.57)	11.09 (2.65)	40.12***	1.20

Notes.

a. *** $p < .001$, two-tailed paired-sample *t*-test.
b. Effect size: Calculated as Cohen's *d* by dividing the difference between posttest and pretest mean scores by the pooled standard deviation (square root of the average of the squared standard deviations).